# NASA/TM-2000-209891, Vol. 86



# Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall, Editor

# Volume 86 BOREAS Level-0 ER-2 Navigation Data

R. Strub, J.A. Newcomer, and R. Dominguez

National Aeronautics and Space Administration

**Goddard Space Flight Center** Greenbelt, Maryland 20771

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# Volume 86 BOREAS Level-0 ER-2 Navigation Data

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# **BOREAS Level-0 ER-2 Navigation Data**

Richard Strub, Roseanne Dominguez, Jeffrey A. Newcomer

# Summary

The BOREAS Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data. The level-0 ER-2 navigation data files contain aircraft attitude and position information acquired during the digital image and photographic data collection missions. Temporally, the data were acquired from April to September 1994. Data were recorded at intervals of 5 seconds. The data are stored in tabular ASCII files.

Note that the level-0 ER-2 navigation data are not contained on the BOREAS CD-ROM set. An inventory listing file is supplied on the CD-ROM to inform users of the data that were collected. See Section 15 for information about how to acquire actual level-0 ER-2 navigation data.

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### 1. Data Set Overview

### 1.1 Data Set Identification

BOREAS Level-0 ER-2 Navigation Data

### 1.2 Data Set Introduction

The BOReal Ecosystem-Atmosphere Study (BOREAS) Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data.

### 1.3 Objective/Purpose

The ER-2 navigation data set consists of navigation parameters gathered by the aircraft's onboard systems in support of the payload instruments. The purpose of the data is to provide general aircraft positioning information and aircraft attitude information during data collection activities.

### 1.4 Summary of Parameters

The data include times and georeferencing information that can be used to determine temporal and spatial coordinates associated with each measurement collected from the onboard instruments.

### 1.5 Discussion

The ER-2 navigation data set consists of navigation parameters gathered by the aircraft's onboard systems in support of the payload instruments. It includes times and georeferencing information that can be used to determine temporal and spatial coordinates associated with each measurement collected from the above instruments.

### 1.6 Related Data Sets

BOREAS Level-0 ER-2 Aerial Photography BOREAS Level-0 AOCI Imagery: Digital Counts in BIL Format BOREAS Level-0 Daedalus TMS Imagery: Digital Counts in BIL Format BOREAS RSS-18 Level-1B AVIRIS Imagery: At-sensor Radiance in BIL Format

# 2. Investigator(s)

### 2.1 Investigator(s) Name and Title

**BOREAS Staff Science** 

# 2.2 Title of Investigation

BOREAS Staff Science Aircraft Data Acquisition Program

### 2.3 Contact Information

#### Contact 1:

Jeffrey S. Myers Aircraft Data and Sensor Facilities NASA Ames Research Center MS 240-6 (Bldg. 240, Rm. 219) Moffett Field, CA 94035-1000 (415) 604-6253 (415) 604-4987 (fax) jmyers@arc.nasa.gov

### Contact 2:

Jeffrey A. Newcomer Raytheon ITSS Code 923 NASA GSFC Greenbelt, MD 20771 (301) 286-7858 (301) 286-0239 (fax) Jeffrey.Newcomer@gsfc.nasa.gov

# 3. Theory of Measurements

The National Aeronautics and Space Administration (NASA) at Ames Research Center (ARC) maintains a variety of aircraft and sensor systems dedicated to support of remote sensing research. Among these is the Lockheed ER-2 (U-2R). The ER-2 has carried the Moderate-Resolution Imaging Spectrometer (MODIS) Airborne Simulator (MAS), the Multispectral Atmospheric Mapping Sensor (MAMS), the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), the Thematic Mapper Simulator (TMS), the Airborne Ocean Color Imager (AOCI), and the Thermal Infrared Multispectral Scanner (TIMS). For the BOREAS project, the TMS, AOCI, and AVIRIS sensors flew aboard the ER-2.

Navigation parameters provided by the Litton LTN-92 Inertial Navigation System (INS) includes latitude/longitude, altitude, air speed, pitch, roll, heading, wind speed and direction, and static air temperature. The data were recorded in 5-second intervals.

# 4. Equipment

### 4.1 Sensor/Instrument Description

#### 4.1.1 Collection Environment

The INS on the ER-2 is a Litton LTN-92. The LTN-92 comprises three separate units: the Inertial Navigation Unit (INU), the Control/Display Unit (CDU), and the Mode Select Unit (MSU). Three 28-cm ring laser gyros and a triad of force rebalanced accelerometers make up the LTN-92's instrument cluster. The system accepts Area Navigation (RNAV), Global Positioning System (GPS), or manual position updates, plus INS mixing for improved performance. The Litton Web site (http://www.littoncorp.com/html/newsflash/06\_14\_97.htm) can be referenced for more information.

The system operates by sensing accelerations from a gyro-stabilized, all-attitude platform. This information is integrated by a digital computer to provide an indication of present position (latitude and longitude), attitude data (pitch and roll), and course line computation referenced to great circle routes. The ER-2 has no room for auxiliary personnel; the LTN-92 INU, the instrument control panel, and the temperature and pressure units are directly connected to the data recorder in the payload area.

### 4.1.2 Source/Platform

The NASA ER-2 is a high-altitude, single-pilot aircraft based at ARC in Moffett Field, CA, and is deployed globally in support of a variety of atmospheric research projects. It has a maximum altitude of 70,000 feet (21 km), a range of 3,000 nautical miles, a maximum flight duration of 8 hours (nominal 6.5 hours), and a top speed of 410 knots true air speed. The aircraft accommodates about 2,700 pounds of payload and offers the following science support systems:

- Inertial navigation
- Satellite NBS Time Code receiver
- Navigation data recording system
- Real-time telemetry data link

### 4.1.3 Source/Platform Mission Objectives

For BOREAS, the primary ER-2 mission objective was to collect various Earth surface data in coordination with satellite overpasses for data verification and integration studies. A secondary objective was to collect data at key times when the satellites were not within range of specific sites. The ER-2 was based in Spokane, WA, and could be deployed from there to take advantage of anticipated good data collection conditions. The navigation data provide in-flight geographic location and attitude information for the onboard sensors.

### 4.1.4 Key Variables

The key parameters used by BOREAS Information System (BORIS) staff and investigators are geographic location, time, platform attitude, altitude, aircraft pitch and roll, and temperature in proximity to the aircraft.

### 4.1.5 Principles of Operation

The INS on the ER-2 operates by sensing accelerations from a gyro-stabilized, all-attitude platform. This information is integrated by a digital computer to provide an indication of present position (latitude and longitude), attitude data (pitch and roll), and course line computation referenced to great circle routes.

### 4.1.6 Sensor/Instrument Measurement Geometry

Aboard the ER-2, navigation parameters are recorded at 5-second intervals. The data buffer servicing the navigation recorder samples the particular parameter between records, but is precisely correct only at some point between records. Each parametric measurement is recorded as a count in a 16-bit word; consequently, the conversion of that count to an engineering unit defines the precision. The precision of each measurement is tabulated below.

Parameter	Precision
Julian Date	One day
Time	One second
Latitude	0.33 minutes of angle (2002.6 feet)
Longitude	0.33 minutes of angle (2002.6 feet)
N-S Velocity	0.1 knot
E-W Velocity	0.1 knot
True Heading	0.0054932 degrees of an angle
Ground Speed	0.1 knot
Vertical Velocity	0.025 feet/second
Altitude	2.92749 feet (pressure altitude)
True Air Speed	0.0152588 knot
Pitch	0.0054932 degrees of an angle
Roll	0.0054932 degrees of an angle
Computed:	
Ground Speed	1.0 nautical mile per hour
Wind Speed	1.0 nautical mile per hour
Wind Direction	1.0 degree
Vertical Velocity	1.0 foot per second
Climb Angle	1.0 degree
Air Temperature	0.1 degree centigrade

The accuracy of the X-Y-Z position as recorded by the navigation system is limited by the frequency and accuracy of the Tactical Air Navigation (TACAN)-based updates to the inertial system and the accuracy of the recorded altitude. In the conterminous United States, updates occur frequently and are based on strong relative geometry because of the density of TACAN stations, resulting in errors of less than 0.1 nautical mile in X and Y (less error than the precision of the recording system). Altitude is based on barometric pressure with standard pressure defined as 29.92 inches of mercury. Consequently, the actual altitude above mean sea level will vary with current atmospheric conditions and the actual altitude above terrain with the terrain elevation.

### 4.1.7 Manufacturer of Sensor/Instrument

ARC personnel built the navigation data recorder specifically for NASA's ER-2 fleet.

LTN-92 INU Litton Industries, Inc. Woodland Hills, CA 91367-6675

### 4.2 Calibration

### 4.2.1 Specifications

None given.

### 4.2.1.1 Tolerance

None given.

# 4.2.2 Frequency of Calibration

None given.

### 4.2.3 Other Calibration Informati

# 5. Data Acquisition Methods

The ER-2 has no room for auxiliary personnel; the LTN-92 INV, the GPS, the instrument control panel, and the temperature and pressure units are connected to the payload area by RS232 and Aeronautical Radio, Inc. (ARINC) 429 data buses.

Data are recorded serially as a flux change on both track 1 and track 2, with a flux change on track 1 representing a logic one and a flux change on track 2 representing a logic zero. Data words are grouped with 16 bits per word and are separated by a three-step gap in which no flux changes occur on either track. After 1316-bit words (or up to 21 words, depending upon how many analog channels have been recorded), a 12-bit end-of-file gap is recorded (no flux changes). The order of words is as follows:

```
WORD
             DESCRIPTION
Serial Number, Flags, Julian Date
Clock
Latitude
Longitude
N-S Velocity
E-W Velocity
True Heading
Ground Speed (valid data only with standard INS)
Vertical Velocity (valid data only with high-resolution INS)
Altitude
True Air Speed
Pitch
Roll
14-21
            Analog Inputs (optional)
```

For more detailed information on the Cassette Data Format see Guillot, 1985.

### 6. Observations

#### 6.1 Data Notes

None. Pertinent in-flight comments are recorded in the digital data records.

### 6.2 Field Notes

Flight summary reports and verbal records on videotapes are available from the ER-2 flights.

# 7. Data Description

### 7.1 Spatial Characteristics

### 7.1.1 Spatial Coverage

The BOREAS level-0 ER-2 navigation data were collected primarily as the ER-2 flew over portions of the Southern Study Area (SSA) and the Northern Study Area (NSA) during its image data acquisition missions. The SSA and the NSA are located in the southwest and northeast portions of the overall BOREAS region. Some navigation data exist in the data set that cover the BOREAS transect area between the SSA and NSA and areas outside the BOREAS region.

The North American Datum of 1983 (NAD83) corner coordinates of the SSA are:

	Latitude	Longitude
Northwest	54.321 N	106.228 W
Northeast	54.225 N	104.237 W
Southwest	53.515 N	106.321 W
Southeast	53.420 N	104.368 W

The NAD83 corner coordinates of the NSA are:

	Latitude	Longitude		
Northwest	56.249 N	98.825 W		
Northeast	56.083 N	97.234 W		
Southwest	55.542 N	99.045 W		
Southeast	55.379 N	97.489 W		

# 7.1.2 Spatial Coverage Map

Not available.

### 7.1.3 Spatial Resolution

Spatial resolution is not strictly applicable to ER-2 navigational data. The sampling rate for each portion of the navigation data can be combined with aircraft position, speed, and altitude to derive a spatial component for each data sample. However, because of the 5-second duration between each navigation parameter, interpolating the navigation data to specific lines in the image data may have limited usefulness.

#### 7.1.4 Projection

The BOREAS level-0 ER-2 navigation data contain latitude and longitude coordinates in the parameter set. Although the latitude and longitude coordinates could be used to calculate coordinates for any map projection, BORIS staff did not assess their accuracy and therefore cannot make any statements about their validity.

### 7.1.5 Grid Description

Not applicable.

### 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage

The data were collected during BOREAS' Focused Field Campaign (FFC) and three Intensive Field Campaigns (IFCs), covering the period from 19-Apr-1994 through 17-Sep-1994. The ER-2 collected various image data sets over the BOREAS sites in 1996, but no navigation data were delivered to BORIS.

# 7.2.2 Temporal Coverage Map

	IFC#	Dates	
]	FFC-T	16-Apr-1994	 20-Apr-1994
	IFC-1	23-May-1994	 08-Jun-1994
	IFC-2	21-Jul-1994	 08-Aug-1994
	IFC-3	08-Sep-1994	 17-Sep-1994

### 7.2.3 Temporal Resolution

All of the parameters in the navigation data were collected at intervals of 5 seconds.

### 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

A listing of the navigation data file parameters is given in Section 8.2. The parameters contained in the inventory listing file on the CD-ROM are:

### 7.3.2 Variable Description/Definition

A detailed description of the navigation data parameters is given in Section 8.2. The parameters in the CD-ROM inventory listing are:

Column Name	Description
SPATIAL_COVERAGE	The general term used to denote the spatial area over which the data were collected.
DATE_OBS	The date on which the data were collected.
START_TIME	The starting Greenwich Mean Time (GMT) for the data collected.
END_TIME	The ending Greenwich Mean Time (GMT) for the data collected.
ER2_MISSION_ID	The mission identifier assigned to the ER2 mission in the form of YY-DDD where YY is the last two digits of the fiscal year, and DDD is the deployment number. An example would be 94-120.

The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).

Missng Unrel Below

### 7.3.3 Unit of Measurement

A detailed description of the navigation data parameter units is given in Section 8.2. The measurement units for the parameters contained in the inventory listing file on the CD-ROM are:

Column Name		Units
SPATIAL_COVERAGE	[none]	
DATE_OBS	[DD-MON-YY]	
START_TIME	[HHMM GMT]	
END_TIME	[HHMM GMT]	
ER2_MISSION_ID	[none]	
CRTFCN CODE	[none]	

### 7.3.4 Data Source

A detailed description of the navigation data files and their content is given in Section 8.2. The sources of the parameter values contained in the inventory listing file on the CD-ROM are:

Column Name	Data Source
SPATIAL COVERAGE	[Constant software parameter value]
DATE_OBS	[Navigation data files]
START_TIME	[Navigation data files]
END_TIME	[Navigation data files]
ER2_MISSION_ID	[ER2 mission information]
CRTFCN_CODE	[Constant data base value]

### 7.3.5 Data Range

The range of values for the parameters in the actual navigation data files was not tabulated. The following table gives information about the parameter values found in the inventory table on the CD-ROM.

Maximum

Minimum

Column Name	Data Value	Data Value	Data Value	Data Value	Detect Limit	Not Cllctd
SPATIAL_COVERAGE DATE_OBS START_TIME END_TIME ER2_MISSION_ID CRTFCN_CODE	N/A 19-APR-94 1310 1920 94-079 PRE	N/A 17-SEP-94 1630 2215 94-143 PRE	None None None None None	None None None None None	None None None None None	None None None None None
Minimum Data Value The minimum value found in the column.  Maximum Data Value The maximum value found in the column.  Missng Data Value The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.  Unrel Data Value The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be						

```
unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
                   -- This value indicates that no attempt was made to
Data Not Cllctd
                      determine the parameter value. This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.
Blank -- Indicates that blank spaces are used to denote that type of value.
N/A -- Indicates that the value is not applicable to the respective column.
None -- Indicates that no values of that sort were found in the column.
```

### 7.4 Sample Data Record

A sample data record for the level-0 ER-2 navigation data is not available here. The following are the records from the level-0 ER-2 navigation data inventory table on the CD-ROM:

```
SPATIAL_COVERAGE, DATE_OBS, START_TIME, END_TIME, ER2_MISSION_ID, CRTFCN_CODE
'SSA',19-APR-94,1630,2215,'94-079','PRE'
'NSA',20-APR-94,1555,2155,'94-080','PRE'
'TRANSECT', 20-APR-94, 1555, 2155, '94-080', 'PRE'
'NSA', 28-APR-94, 1445, 2050, '94-082', 'PRE'
'TRANSECT', 28-APR-94, 1445, 2050, '94-082', 'PRE'
'NSA',08-JUN-94,1345,1945,'94-102','PRE'
'TRANSECT', 08-JUN-94, 1345, 1945, '94-102', 'PRE'
'SSA',21-JUL-94,1500,2040,'94-120','PRE'
'NSA',04-AUG-94,1310,1920,'94-123','PRE'
'SSA',04-AUG-94,1310,1920,'94-123','PRE'
'TRANSECT',04-AUG-94,1310,1920,'94-123','PRE'
'NSA',08-AUG-94,1314,1937,'94-124','PRE'
'SSA',08-AUG-94,1314,1937,'94-124','PRE'
'TRANSECT', 08-AUG-94, 1314, 1937, '94-124', 'PRE'
'SSA',16-SEP-94,1500,2100,'94-142','PRE'
'NSA',17-SEP-94,1355,2005,'94-143','PRE'
'TRANSECT',17-SEP-94,1355,2005,'94-143','PRE'
'SSA',17-SEP-94,1355,2005,'94-143','PRE'
```

# 8. Data Organization

### 8.1 Data Granularity

The smallest unit of level-0 ER-2 navigation data is all the ER-2 navigation information collected during the ER-2 flights over the BOREAS areas. All nine of the data files are in a single tar file on a single tape for distribution.

### **8.2 Data Format(s)**

The CD-ROM inventory listing file consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no

spaces between the fields.

The data are contained in a single tar file and after extraction (tar -xvf) can be seen correctly if unblocked using a block size of 150. (dd if=in\_fn ibs=150 cbs=150 obs=150 conv=unblock of=out fn).

```
FLIGHT 94-079 DATE 19-APR-94:16:30
FLIGHT 94-080 DATE 20-APR-94:15:55
FLIGHT 94-082 DATE 28-APR-94:14:45
FLIGHT 94-102 DATE 08-JUN-94:13:45
FLIGHT 94-120 DATE 21-JUL-94:15:00
FLIGHT 94-123 DATE 04-AUG-94:13:10
FLIGHT 94-124 DATE 08-AUG-94:13:14
FLIGHT 94-142 DATE 16-SEP-94:15:00
FLIGHT 94-143 DATE 17-SEP-94:13:55
```

Each data file contains a header record that is formatted as described in the following table:

# U2/USER PLUS DIGITIZED ANALOG VALUES HEADER INFORMATION

CHARACTERS	CONTENTS
RECORD 1	
2 - 7	"FLIGHT"
9 - 14	The flight identifier, which consists of the last two digits of the fiscal year, a dash, and a three-digit unique number that identifies the flight within the fiscal year (e.g., 92-001)
17 - 20	"DATE"
22 - 29	The date of the flight at liftoff, in the form MM/DD/YY, where MM gives the number of the month DD gives the day
	YY gives the last two digits of the current year
32 - 34	"A/C"
36 - 38	Tail number of the aircraft (706, 708, or 709)
41 - 47	"TAKEOFF"
49 - 56	The takeoff time, in the form HH:MM/DD, where HH gives the hour (24-hour clock) MM gives the minute DD gives the day of the month at takeoff
59 - 62	"LAND"
64 - 71	The landing time, in the same form as "TAKEOFF," except that DD gives the day of the month at landing
82 - 101	"RECORDER UNIT NUMBER"
103	ID number of the navigation data recorder
104 - 200	Blank
RECORDS 2 - 5	Title that serves to label the contents of the data records.

NOTE: Characters not explicitly mentioned here are filled with blanks; i.e., the American Standard Code for Information Interchange (ASCII) code for "space."

(END of Table E-6A)

The data part of each file is formatted as described in the following table:

# U2/USER PLUS DIGITIZED ANALOG VALUES DATA RECORD FORMAT

(English Units)

CHARACTER	CONTENTS
02 - 12	The time and day in the form HH:MM:SS/DD, where HH gives the hour (24-hour clock)
	MM gives the minute SS gives the second
	DD gives the day of the month
15	Time source indicator
(GOES)	"G" from Geostationary Operational Environmental Satellite
	"I" Internal time source
18 - 25	Latitude, hHH:MM.t, as follows:
18	h hemisphere, "N" for northern, or "S" for southern
19 - 20	DD Degrees of latitude
21	: separator between degrees and minutes
22 - 25	MM.t Minutes and tenths of minutes of latitude
	(with a decimal point)
27 - 35	Longitude, hDDD:MM.t, as follows:
27	h hemisphere, "W" for western, or "E" for eastern
28 - 30	DDD Degrees of longitude
31	: separator between degrees and minutes
32 - 35	MM.t Minutes and tenths of minutes of longitude
	(with a decimal point)
37 - 41	Altitude, in feet (from 0 - 70000)
42	"space" if below 70,000 feet, or
	"+" if over 70,000 feet, (if over 70,000 feet, the
	altitude (37-41) will contain 70000)
45 - 47	True air speed, in nautical miles per hour
49 - 53	Aircraft pitch, in degrees, given to tenths (with a decimal
	point); positive indicates nose up
55 - 59	Aircraft roll, in degrees, given to tenths (with a decimal
	point; positive indicates right roll; (i.e., right wing down)
61 - 66	True heading, in degrees, given to tenths (with a decimal
	Point); zero degrees indicates north, positive to the
	east of north (90 indicates due east; 180 indicates
68 80	south; and 270 indicates west)
67 - 72	North-South velocity, in nautical miles per hour
74 - 77	East-West velocity, in nautical miles per hour
79 - 82	Vertical velocity, in feet per second
85 - 87	Ground speed, in nautical miles per hour
94 - 96	Computed ground speed, in nautical miles per hour (square
	root of the sum of the squares of the north-south and east-west velocities)
100 - 103	Computed wind speed, in nautical miles per second (the vector
100 - 103	difference of the true air speed and true heading and
	north-south and east-west velocities
107 - 109	Computed wind direction, in degrees from north (clockwise is
101 - 109	positive)
113 - 116	Computed vertical velocity (in feet per second) computed

	from the altitude difference and time difference
	between consecutive records
122 - 124	Computed angle of attack (degrees); i.e., arcsine (vertical
	velocity divided by ground speed)
134 - 138	Static air temperature in degrees C, computed from the first
	digitized analog value, if recorded

# 9. Data Manipulations

### 9.1 Formulae

None.

# 9.1.1 Derivation Techniques and Algorithms

None.

### 9.2 Data Processing Sequence

### 9.2.1 Processing Steps

BORIS staff processed the level-0 ER-2 navigation data by extracting pertinent header information from the navigation file and loading the online data base with needed information.

### 9.2.2 Processing Changes

ARC applied no special or additional processing to the ER-2 navigation data from BOREAS.

### 9.3 Calculations

# 9.3.1 Special Corrections/Adjustments

ARC made no special adjustments or offsets to the data.

### 9.3.2 Calculated Variables

ARC made no special adjustments or offsets to the data.

### 9.4 Graphs and Plots

None.

### 10. Errors

### 10.1 Sources of Error

The data buffer servicing the navigation recorder samples the particular parameter between records, but is precisely correct only at some point between records. Each parametric measurement is recorded as a count in a 16-bit word; consequently the conversion of that count to an engineering unit defines the precision.

### 10.2 Quality Assessm10.2.1 Data Validation by Source

Data distribution to NASA ARC occurs at the conclusion of the deployment. Data tapes are presented in total for documentation and archive. Data evaluation consists primarily of identifying component failure (i.e., radar altitude, GPS values, and pressure measurements).

### 10.2.2 Confidence Level/Accuracy Judgment

The quality of the data is judged to be good.

### 10.2.3 Measurement Error for Parameters

See Sections 4.1.6 and 8.2.

# 10.2.4 Additional Quality Assessments

BORIS staff imported selected navigation files into a spreadsheet and graphed the values to check for reasonableness.

### 10.2.5 Data Verification by Data Center

BORIS staff reviewed the contents of the data files for consistency and used portions of the information to inventory and describe the data in the relational data base.

### 11. Notes

### 11.1 Limitations of the Data

None.

### 11.2 Known Problems with the Data

None.

### 11.3 Usage Guidance

The tar file should be copied from tape to disk. All nine ASCII files are contained in a single tar file and should be extracted (tar -xvf filename). Each file should then be placed into 150-byte records. This can be accomplished by the UNIX command dd:

dd if=nav.94-123 of=filename ibs=150 cbs=150 obs=150 conv=unblock

The files will then appear as 19 ASCII columns with a 5-line header.

### 11.4 Other Relevant Information

Not applicable.

# 12. Application of the Data Set

The ER2 navigation data could be used: 1) To possibly improve the positional location of the aircraft scanner data and 2) As inputs to software for automated geometric and geographic correction of the aircraft scanner data. As a word of caution, the accuracy and precision of these data are not as well known as those from the C130 aircraft and in addition, it is not known if the frequency of navigation observations is sufficient to properly correct distortions in the scanner data.

### 13. Future Modifications and Plans

No modification is planned for the ER-2 navigation data currently logged in the BORIS data base.

### 14. Software

### 14.1 Software Description

The UNIX dd command is useful in placing the new-line characters in the correct place so that the ASCII file appears correctly. See Section 11.3. BORIS staff developed software to extract needed information from the data files and inventory the ER-2 navigation data in the relational data base.

#### 14.2 Software Access

The software developed by BORIS staff can be obtained by contacting BORIS personnel or the ORNL DAAC.

### 15. Data Access

The level-0 ER-2 navigation data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

### 15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services Oak Ridge National Laboratory P.O. Box 2008 MS-6407 Oak Ridge, TN 37831-6407 Phone: (423) 241-3952

Fax: (423) 574-4665

E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

### 15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

# 15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

### 15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

# 16. Output Products and Availability

### 16.1 Tape Products

The BOREAS level-0 ER-2 navigation data can be made available on 8-mm, Digital Archive Tape (DAT), or 9-track tapes at 1600 or 6250 Bytes Per Inch (BPI).

### 16.2 Film Products

Color aerial photographs and video records were made during data collection. The video record includes aircraft crew cabin intercom conversations and an audible tone that was initiated each time the sensors were triggered. The BOREAS data base contains an inventory of available BOREAS aircraft flight documentation, such as flight logs, videotapes, and photographs.

### 16.3 Other Products

Although the inventory is contained on the BOREAS CD-ROM set, the actual level-0 ER-2 navigation data are not. See Section 15 for information about how to obtain the data.

### 17. References

# **17.1 Platform/Sensor/Instrument/Data Processing Documentation** Ekstrand, R.E. and D. Wolf. 6 May 1992. INSPLOT.

Guillot, D. 1 April 1985. Cassette Data Format for the U-2 navigation recorder.

17.2 Journal Articles and Study Reports

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

# 17.3 Archive/DBMS Usage Documentation None.

# 18. Glossary of Terms

None.

# 19. List of Acronyms

A/D - Analog-digital

AOCI - Airborne Ocean Color Imager

ARC - Ames Research Center ARINC - Aeronautical Radio, Inc.

ASAS - Advanced Solid-State Array Spectroradiometer

ASCII - American Standard Code for Information Interchange AVIRIS - Airborne Visible and Infrared Imaging Spectrometer

BIL - Band Interleaved by Line

BOREAS - BOReal Ecosystem-Atmosphere Study

BORIS - BOREAS Information System

BPI - Bytes Per Inch

CCT - Computer Compatible Tape CD-ROM - Compact Disk-Read-Only Memory

CDU - Control/Display Unit

DAAC - Distributed Active Archive Center

DAT - Digital Archive Tape EOS - Earth Observing System

EOSDIS - EOS Data and Information System

FFC - Focused Field Campaign

FFC-T - Focused Field Campaign - Thaw GIS - Geographic Information Sys GMT - Greenwich Mean Time GPS - Global Positioning System - Geographic Information System

GSFC - Goddard Space Flight Center HTML- HyperText Markup Language IFC - Intensive Field Campaign INS - Inertial Navigation System INU - Inertial Navigation Unit

MAMS - Multispectral Atmospheric Mapping Sensor

MAS - MODS Airborne Simulator

MODIS - Moderate-Resolution Imaging Spectrometer

MSU - Mode Select Unit

NAD83 - North American Datum of 1983

NASA - National Aeronautics and Space Administration

NBS - National Bureau of Standards

NBS - Nactional

NSA - Northern Study Area

ORNL - Oak Ridge National Laboratory PANP - Prince Albert National Park PRT-5 - Precision Radiation Thermometer

RNAV - Area Navigation

RSS - Remote Sensing Science

S/D - synchro-digital

SCSI - Small Computer Serial Interface

SGI - Silicon Graphics IRIX SSA - Southern Study Area TACAN - Tactical Air Navigation

TAS - True Air Speed

TIMS - Thermal Infrared Multispectral Scanner

TMS - Thematic Mapper Simulator URL - Uniform Resource Locator

# 20. Document Information

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When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

The BOREAS level-0 ER-2 navigation data were collected and processed from the original aircraft tapes by personnel of the Medium Altitude Aircraft Branch at NASA ARC. BORIS staff reviewed, repackaged, and documented the data received from ARC into the current product. The contributions of ARC and BORIS staff to enhancing and checking this data set are greatly appreciated.

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#### 13. ABSTRACT (Maximum 200 words)

The BOREAS Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition, processing, and archiving of aircraft navigation/attitude data to complement the digital image data. The level-0 ER-2 navigation data files contain aircraft attitude and position information acquired during the digital image and photographic data collection missions. Temporally, the data were acquired from April to September 1994. Data were recorded at intervals of 5 seconds. The data are stored in tabular ASCII files.

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